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Gukeisen

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(54) **FAN VARIABLE AREA NOZZLE FOR A GAS TURBINE ENGINE FAN NACELLE WITH SLIDING ACTUATION SYSTEM**

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F02K 1/12	(2006.01)
F02K 3/06	(2006.01)
F02K 3/075	(2006.01)

(52) **U.S. Cl.**

CPC ***F02K 1/1253*** (2013.01); ***F02K 3/06*** (2013.01); ***F02K 3/075*** (2013.01); *F05D 2260/50* (2013.01)

(58) **Field of Classification Search**

USPC 60/39.5, 770, 771, 772; 239/265.19, 239/265.33, 265.35, 265.39

See application file for complete search history.

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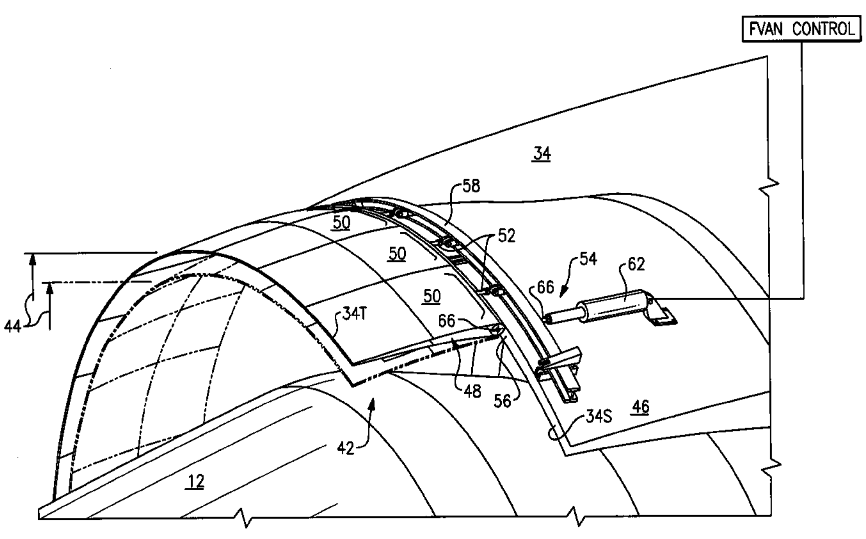
(57) **ABSTRACT**

A fan variable area nozzle (FVAN) includes a flap assembly which varies a fan nozzle exit area. An actuator system drives a sliding drive ring relative a multitude of slider tracks mounted to a fan nacelle to adjust each flap of the flap assembly through the flap linkage to pitch the flap assembly about a circumferential hinge line to vary the diameter of the annular fan nozzle exit area between the fan nacelle and the core nacelle. The FVAN may be separated into a multiple of drive ring sectors which are each independently adjustable by an associated actuator of the actuator system to provide a low profile drag asymmetrical fan nozzle exit area.

16 Claims, 5 Drawing Sheets



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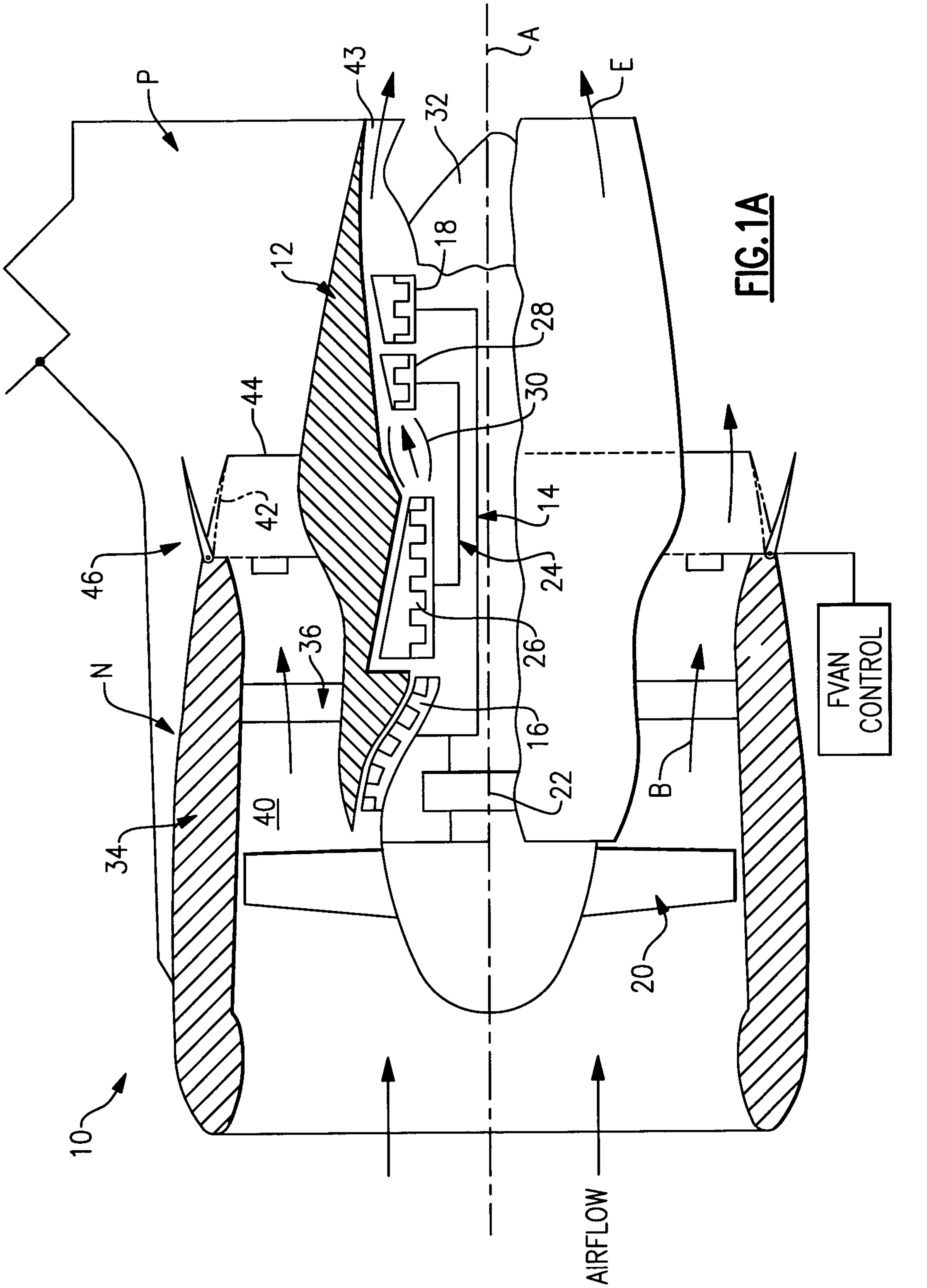
FVAN
CONTROL
AIRFLOW
10
12
14
16
18
20
22
24
26
28
30
32
34
36
40
42
43
44
46
A
B
E
N
P

FIG.1A

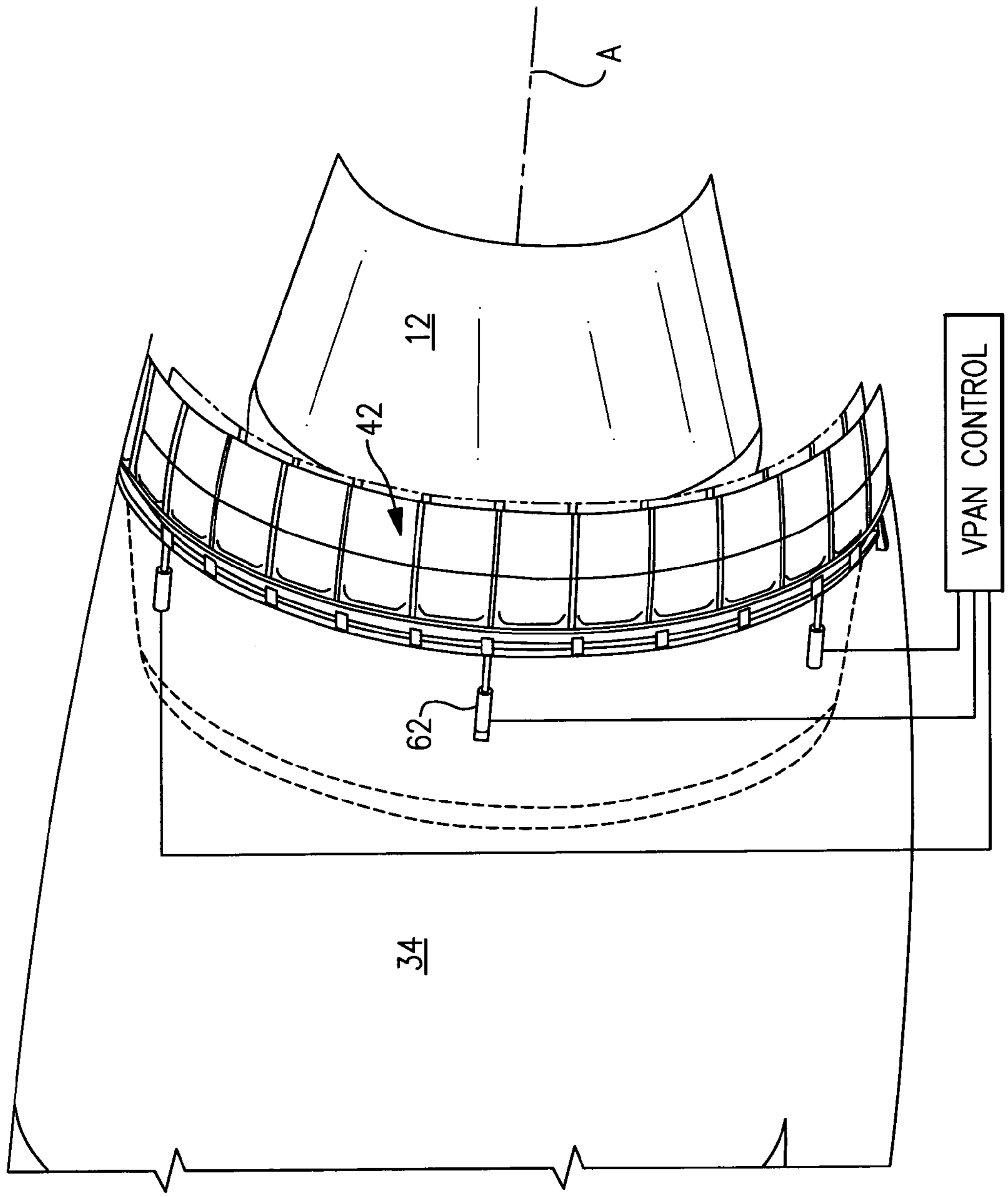

FIG.1B

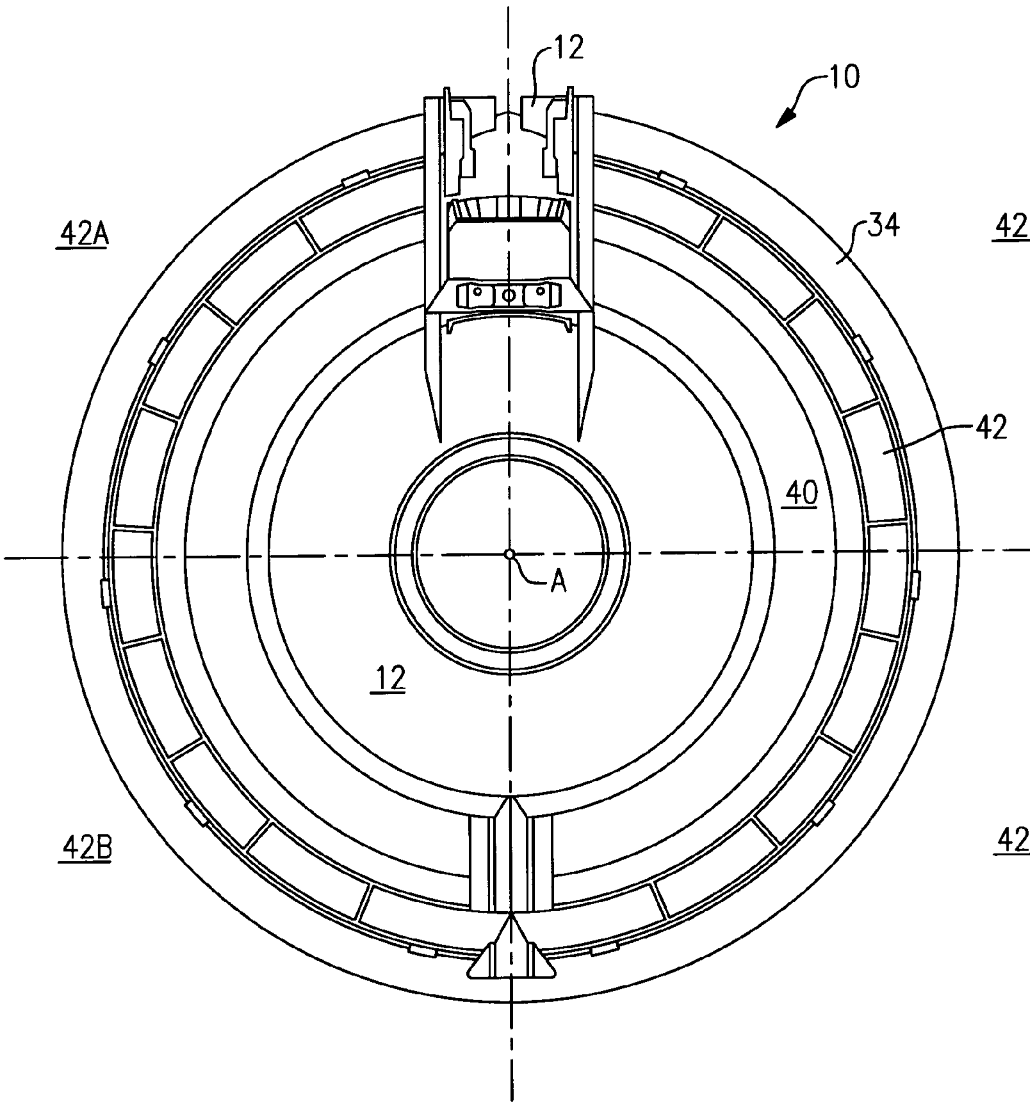

FIG.1C

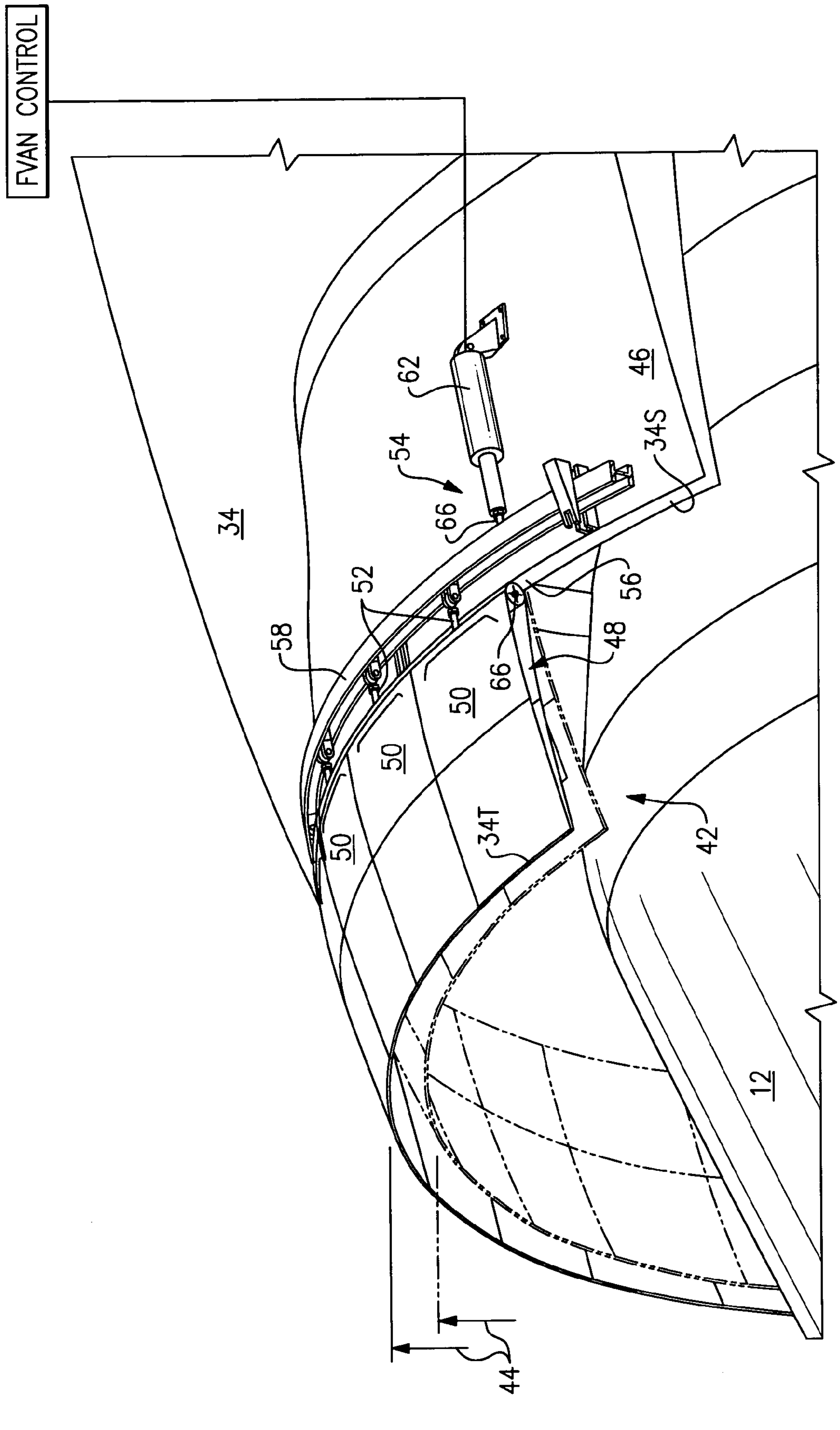
FVAN CONTROL
34
62
54
66
46
34S
52
58
56
48
66
50
50
50
50
42
34T
12
44

FIG.2A

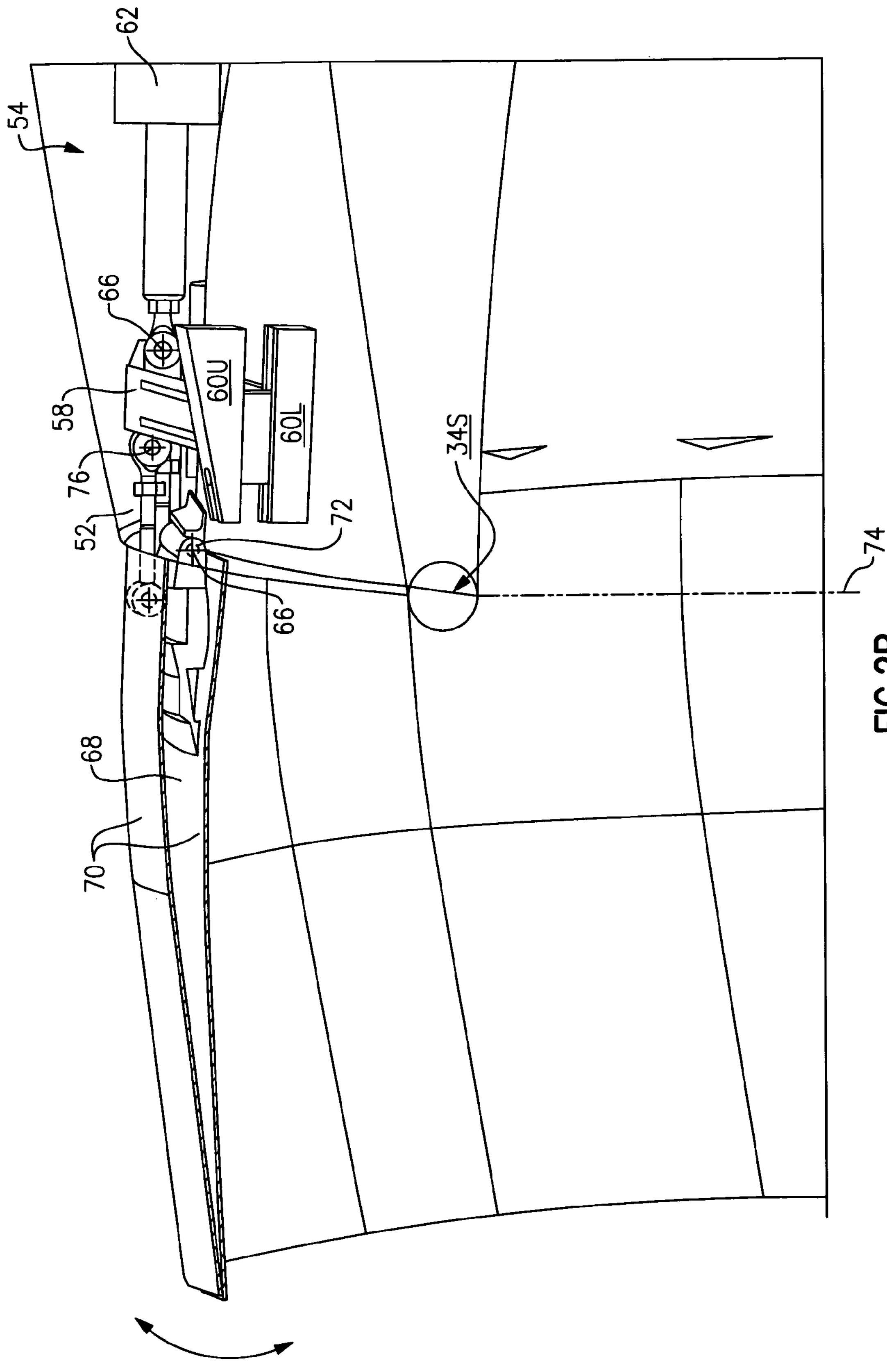

FIG.2B

FAN VARIABLE AREA NOZZLE FOR A GAS TURBINE ENGINE FAN NACELLE WITH SLIDING ACTUATION SYSTEM

BACKGROUND OF THE INVENTION

The present invention relates to a gas turbine engine, and more particularly to a turbofan engine having a sliding drive ring FVAN.

Conventional gas turbine engines generally include a fan section and a core engine with the fan section having a larger diameter than that of the core engine. The fan section and the core engine are disposed about a longitudinal axis and are enclosed within an engine nacelle assembly.

Combustion gases are discharged from the core engine through a core exhaust nozzle while an annular fan flow, disposed radially outward of the primary airflow path, is discharged through an annular fan exhaust nozzle defined between a fan nacelle and a core nacelle. A majority of thrust is produced by the pressurized fan air discharged through the fan exhaust nozzle, the remaining thrust being provided from the combustion gases discharged through the core exhaust nozzle.

The fan nozzles of conventional gas turbine engines have a fixed geometry. The fixed geometry fan nozzles are a compromise suitable for take-off and landing conditions as well as for cruise conditions. Some gas turbine engines have implemented fan variable area nozzles. The fan variable area nozzle provide a smaller fan exit nozzle diameter during cruise conditions and a larger fan exit nozzle diameter during take-off and landing conditions. Existing fan variable area nozzles typically utilize relatively complex mechanisms that increase overall engine weight to the extent that the increased fuel efficiency therefrom may be negated.

Accordingly, it is desirable to provide an effective, lightweight fan variable area nozzle for a gas turbine engine.

SUMMARY OF THE INVENTION

A fan variable area nozzle (FVAN) according to the present invention includes a flap assembly which varies a fan nozzle exit area. The flap assembly is incorporated into an end segment of the fan nacelle to include a trailing edge thereof.

The flap assembly generally includes a multiple of flaps, flap linkages and an actuator system. The actuator system drives a sliding drive ring relative a multitude of slider tracks mounted to the fan nacelle. The sliding movement of the drive ring drives each flap of the flap assembly through the respective flap linkage to generate pivotal movement of the flap assembly about a circumferential flap hinge line. Pivotal movement of the flap assembly about the circumferential flap hinge line varies the diameter of the annular fan nozzle exit area between the fan nacelle and the core nacelle. By adjusting the FVAN, engine thrust and fuel economy are maximized during each flight regime.

The FVAN may be separated into a multiple of sectors which are each independently adjustable by an associated actuator of the actuator system to provide an asymmetrical fan nozzle exit area to vector thrust therefrom.

The present invention therefore provides an effective, lightweight fan variable area nozzle for a gas turbine engine.

BRIEF DESCRIPTION OF THE DRAWINGS

The various features and advantages of this invention will become apparent to those skilled in the art from the following detailed description of the currently preferred embodiment. The drawings that accompany the detailed description can be briefly described as follows:

FIG. **1**A is a general schematic partial fragmentary view of an exemplary gas turbine engine embodiment for use with the present invention;

FIG. **1**B is a perspective partial fragmentary view of the engine;

FIG. **1**C is a rear view of the engine;

FIG. **2**A is a partial phantom view of the FVAN; and

FIG. **2**B is a sectional view of the FVAN with a linear actuator.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. **1**A illustrates a general partial fragmentary schematic view of a gas turbofan engine **10** suspended from an engine pylon P within an engine nacelle assembly N as is typical of an aircraft designed for subsonic operation.

The turbofan engine **10** includes a core engine within a core nacelle **12** that houses a low spool **14** and high spool **24**. The low spool **14** includes a low pressure compressor **16** and low pressure turbine **18**. The low spool **14** drives a turbofan **20** through a gear train **22**. The high spool **24** includes a high pressure compressor **26** and high pressure turbine **28**. A combustor **30** is arranged between the high pressure compressor **26** and high pressure turbine **28**. The low and high spools **14**, **24** rotate about an engine axis of rotation A.

The engine **10** is preferably a high-bypass geared turbofan aircraft engine. Preferably, the engine **10** bypass ratio is greater than ten (10), the turbofan diameter is significantly larger than that of the low pressure compressor **16**, and the low pressure turbine **18** has a pressure ratio that is greater than five (5). The gear train **22** is preferably an epicycle gear train such as a planetary gear system or other gear system with a gear reduction ratio of greater than 2.5. It should be understood, however, that the above parameters are only exemplary of a preferred geared turbofan engine and that the present invention is likewise applicable to other gas turbine engines.

Airflow enters a fan nacelle **34**, which at least partially surrounds the core nacelle **12**. The turbofan **20** communicates airflow into the core nacelle **12** to power the low pressure compressor **16** and the high pressure compressor **26**. Core airflow compressed by the low pressure compressor **16** and the high pressure compressor **26** is mixed with the fuel in the combustor **30** and expanded over the high pressure turbine **28** and low pressure turbine **18**. The turbines **28**, **18** are coupled for rotation with, respective, spools **24**, **14** to rotationally drive the compressors **26**, **16** and through the gear train **22**, the turbo fan **20** in response to the expansion. A core engine exhaust E exits the core nacelle **12** through a core nozzle **43** defined between the core nacelle **12** and a tail cone **32**.

The core nacelle **12** is supported within the fan nacelle **34** by structure **36** often generically referred to as an upper and lower bifurcation. A bypass flow path **40** is defined between the core nacelle **12** and the fan nacelle **34**. The engine **10** generates a high bypass flow arrangement with a bypass ratio in which approximately 80 percent of the airflow entering the fan nacelle **34** becomes bypass flow B. The bypass flow B communicates through the generally annular bypass flow path **40** and is discharged from the engine **10** through a fan variable area nozzle (FVAN) **42** (also illustrated in FIG. **1**B) which defines a fan nozzle exit area **44** between the fan nacelle **34** and the core nacelle **12**.

Thrust is a function of density, velocity, and area. One or more of these parameters can be manipulated to vary the amount and direction of thrust provided by the bypass flow B. The FVAN **42** changes the physical area and geometry to manipulate the thrust provided by the bypass flow B. However, it should be understood that the fan nozzle exit area **44** may be effectively altered by methods other than structural changes, for example, by altering the boundary layer. Furthermore, it should be understood that effectively altering the fan nozzle exit area **44** is not limited to physical locations approximate the exit of the fan nacelle **34**, but rather, may include the alteration of the bypass flow B at other locations.

The FVAN **42** defines the fan nozzle exit area **44** for discharging axially the fan bypass flow B pressurized by the upstream turbofan **20**. A significant amount of thrust is provided by the bypass flow B due to the high bypass ratio. The turbofan **20** of the engine **10** is preferably designed for a particular flight condition—typically cruise at 0.8M and 35,000 feet.

As the turbofan **20** is efficiently designed at a particular fixed incidence for the cruise condition, the FVAN **42** is operated to vary the fan nozzle exit area **44** for efficient engine operation at other flight conditions, such as landing and take-off and to meet other operational parameters such as noise level. Preferably, the FVAN **42** defines a nominal converged cruise position for the fan nozzle exit area **44** and radially opens relative thereto to define a diverged position for other flight conditions. The FVAN **42** preferably provides an approximately 20% (twenty percent) change in the fan exit nozzle area **44**. It should be understood that other arrangements as well as essentially infinite intermediate positions as well as thrust vectored positions in which some circumferential sectors of the FVAN **42** are converged or diverged relative to other circumferential sectors are likewise usable with the present invention.

The FVAN **42** is preferably separated into four sectors **42**A-**42**D (FIG. **1**C) which are each independently adjustable to asymmetrically vary the fan nozzle exit area **44** to generate vectored thrust. It should be understood that although four segments are illustrated, any number of segments may alternatively or additionally be provided.

In operation, the FVAN **42** communicates with a controller C or the like to adjust the fan nozzle exit area **44** in a symmetrical and asymmetrical manner. Other control systems including an engine controller flight control system may likewise be usable with the present invention. By adjusting the entire periphery of the FVAN **42** symmetrically in which all sectors are moved uniformly, thrust efficiency and fuel economy are maximized during each flight condition. By separately adjusting the circumferential sectors **42**A-**42**D of the FVAN **42** to provide an asymmetrical fan nozzle exit area **44**, engine bypass flow is selectively vectored to provide, for example only, trim balance or thrust controlled maneuvering enhanced ground operations or short field performance.

Referring to FIG. **2**A, the FVAN **42** generally includes a flap assembly **48** which varies the fan nozzle exit area **44**. The flap assembly **48** is preferably incorporated into the fan nacelle **34** to define a trailing edge **34**T thereof. The flap assembly **48** generally includes a multiple of flaps **50**, a respective multiple of flap linkages **52** and an actuator system **54**.

The actuator system **54** includes a multiple of actuators **62** which are fixed to the fan nacelle **34**. Each actuator **62** is mounted to a drive ring **58** at a respective pivotal actuator attachment **66** through a push rod, pitch link, ball joint or other articulatable link or the like.

Referring to FIG. **2**B, each flap **50** is pivotally mounted to the fan nacelle **34** at a hinge **56** and linked to the drive ring **58** through the respective flap linkage **52**. Each flap **50** of the flap assembly **48** generally includes a flap core **68**, an upper flap skin **70**U, and a lower flap skin **70**L. The core **68** is attached to the flap linkage **52** and defines the hinge **56** which pivotally mounts to a fan nacelle segment **34**S at a hinge point **72**. The multiple of hinge points **72** of the flap assembly **48** define a circumferential hinge line **74** of the FVAN **42**. Each hinge **56** may include bearings, bushings or flexures as generally understood. Each flap **50** also includes a nested tongue and groove arrangement such that the flaps are nested when assembled (FIG. **2**A). That is, the skins **70** of each flap **50** preferably engage and overlap an adjacent flap **50** to provide an overlapping flap-seal circumferential interface seal.

The actuators **64** slide axially the drive ring **58** relative a multitude of slider tracks **60** mounted to the fan nacelle **34** to adjust the flap assembly **48** and vary the area defined by the FVAN **28** through which the fan air F is discharged.

The drive ring **58** slides relative the multitude of slider tracks **60** generally along the longitudinal engine axis A. The slider tracks **60** preferably include a lower slider track **60**L an upper slider track **60**U. The upper slider track **60**U may be wedge shaped as the upper slider track **60**U is mounted at a fan nacelle segment **34**S which is tapered at the interface between the fan nacelle **34** and the flap assembly **48**. It should be understood that the slider tracks **60**U, **60**L are preferably shaped to fit within the fan nacelle segment **34**S.

The flap linkage **52** extends from the core **68** and mounts to the drive ring **58** at a flap-ring pivot **76**. The flap-ring pivot **76** is radially offset from the flap hinge points **72** on each flap **50** which define the circumferential flap hinge line **74** for the flap assembly **48**. Preferably, the flap-ring pivot **76** is radially outboard of each flap hinge point **72** relative the engine axis of rotation A.

In operation, the actuator **62** slides the drive ring **58** relative the multitude of slider tracks **60** generally along the longitudinal engine axis A. The sliding movement of the drive ring **58** drives each flap **50** through the flap linkage **52** to result in pivotal movement of the flap assembly **48** about the circumferential hinge line **74**. Pivotal movement of the flap assembly **48** about the flap hinge line **74** varies the diameter of the annular fan nozzle exit area **44** between the fan nacelle **34** and the core nacelle **12**.

By adjusting the FVAN **42**, engine thrust and fuel economy are maximized during each flight regime. Preferably, the actuator assembly **48** communicates with an engine controller or the like to adjust the position of the FVAN **42**. However, other control systems including flight control systems may likewise be usable with the present invention.

The drive ring **58** may be divided into a multiple of sectors such that an associated set of flaps are undependably movable to provide asymmetric operation. That is, the drive ring **58** may be divided into sectors (FIG. **1**C) such that each sector is independently movable to vector a thrust from the FVAN **42**.

The foregoing description is exemplary rather than defined by the limitations within. Many modifications and variations of the present invention are possible in light of the above teachings. The preferred embodiments of this invention have been disclosed, however, one of ordinary skill in the art would recognize that certain modifications would come within the scope of this invention. It is, therefore, to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described. For that reason the following claims should be studied to determine the true scope and content of this invention.

What is claimed is:

1. A nacelle assembly for a gas turbine engine comprising:
a core nacelle defined about an axis;
a fan nacelle mounted at least partially around said core nacelle, said fan nacelle having a fan variable area nozzle defined about said core nacelle;
a drive ring mounted within said fan nacelle;
a flap linkage mounted to each of a multiple of flaps and said drive ring; and,
an actuator system which drives said drive ring along said axis to vary a fan nozzle exit area defined by said fan variable area nozzle.

2. The assembly as recited in claim **1**, wherein said fan variable area nozzle is defined by a multiple of flaps.

3. The assembly as recited in claim **2**, wherein said multiple of flaps define a trailing edge of said fan variable area nozzle.

4. The assembly as recited in claim **1**, wherein said actuator system includes a multiple of linear actuators.

5. The assembly as recited in claim **1**, further comprising a circumferential hinge line defined between said fan variable area nozzle and said fan nacelle, said flap linkage including a flap-ring pivot radially offset from said circumferential hinge line.

6. The assembly as recited in claim **5**, wherein said circumferential hinge line is defined radially inboard relative said flap-ring pivot.

7. The assembly as recited in claim **1**, wherein said fan nozzle exit area defines an at least partially annular fan nozzle exit area between said fan nacelle and said core nacelle.

8. The assembly as recited in claim **1**, wherein said drive ring is divided into a multiple of drive ring segments, each segment including a separately movable flap set of said multiple of flaps.

9. A gas turbine engine comprising:
a core engine defined about an axis;
a gear system driven by said core engine;
a fan driven by said gear system about said axis;
a core nacelle defined at least partially about said core engine; and
a fan nacelle mounted around said fan and at least partially around said core nacelle, said fan nacelle having a fan variable area nozzle with a multiple of flaps which defines a fan nozzle exit area downstream of said fan between said fan nacelle and said core nacelle;
a drive ring mounted within said fan nacelle;
a flap linkage mounted to each of said multiple of flaps and said drive ring; and,
an actuator system which drives said drive ring along said axis to vary a fan nozzle exit area defined by said fan variable area nozzle.

10. The engine as recited in claim **9**, wherein said drive ring is divided in a multiple of segments, each segment including a separately movable flap set of said multiple of flaps and an actuator of said actuator system.

11. A method of varying a fan nozzle exit area of a gas turbine engine comprising the steps of:
(A) locating a fan variable area nozzle which defines a fan nozzle exit area between a fan nacelle and a core nacelle;
(B) axially moving a drive ring disposed within said fan nacelle; and
(C) pitching a flap assembly of the fan variable area nozzle between a first position and a second position to vary at least a sector of the fan nozzle exit area in response to said step (B).

12. A method as recited in claim **11**, wherein said step (C) further comprises:
(a) increasing the fan nozzle exit area during takeoff.

13. A method as recited in claim **12**, wherein said step (B) further comprises:
(a) sliding the drive ring within the fan nacelle.

14. A method as recited in claim **13**, wherein said step (C) further comprises:
(a) pivoting the flap assembly about a circumferential hinge line defined between the fan variable area nozzle and the fan nacelle, a flap linkage of the flap assembly including a flap-ring pivot radially offset from the circumferential hinge line.

15. A method as recited in claim **14**, wherein said step (A) further comprises:
(a) locating the fan variable area nozzle an aft most section of the fan nacelle, the multiple of flaps including a trailing edge of the fan variable area nozzle.

16. A method as recited in claim **14**, wherein said step (B) further comprises:
(a) axially moving a first segment of the drive ring within a fan nacelle relative a second segment; and
(b) asymmetrically adjusting the fan nozzle exit area to vector thrust through the fan variable area nozzle.

* * * * *